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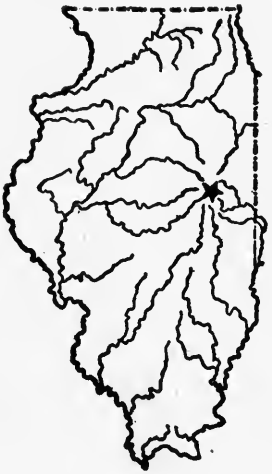
THE FEED COST OF MILK AND FAT PRODUCTION AS RELATED TO YIELDS

By H. A. ROSS, H. F. HALL, and C. S. RHODE



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Summary of Bulletin No. 244

This bulletin presents a method of comparing the feed cost, exclusive of pasture, of milk and of fat production for cows of different annual productions. The study is based upon data obtained from cow-testing association records of 1,605 Holstein cows three years old or over, which were maintained in regions where milk was produced almost entirely for fluid consumption or for condensing.

When these records were divided into groups on the basis of the amount of butter fat produced in one year, the average production of fat for the groups ranged from 93 to 559 pounds, with an average of 263 pounds for the 1,605 cows.

The consumption of concentrates per pound of fat produced was found to be approximately uniform for all groups. The amounts of succulent and dry roughages consumed per pound of fat decreased with an increase in production.

The consumption of digestible nutrients per pound of butter fat produced and the annual production of fat per cow were found to be negatively correlated ($-0.4570 \pm .0133$). With an increase in production, the nutrient consumption per unit of product decreased at an ever-decreasing rate. A theoretical curve was fitted to the observed data, using the formula $Y = \frac{2584.22}{X + 48.06} + 5.18$; in which $Y =$ the pounds of digestible nutrients consumed per pound of fat produced, and $X =$ the annual production of fat in pounds. This formula was used as a basis for comparing the feed cost of fat production for cows of various annual productions.

When current values were applied to the amounts of feed consumed by the various groups of cows, it was found that the cost of feed per pound of digestible nutrients was comparatively uniform, altho slightly higher for the highest-producing cows. The maximum variation for any one year of the fifteen-year period, 1908–1922, was eleven-hundredths of a cent, and for the average of the fifteen-year period it was only six-hundredths of a cent.

When the 1,605 records were divided into classes based on the amount of milk produced annually, the average production for the various groups was found to range from 3,081 pounds to 16,711 pounds, with an average for all the cows of 7,506 pounds.

The correlation coefficient $-0.4180 \pm .0139$ indicates the relation between the annual yield of milk and the nutrient consumption per unit of product. This relation may be expressed by the formula $Y = \frac{3651.60}{X + 36.75} + 14.95$; in which $Y =$ the nutrient consumption per 100 pounds of milk produced, and $X =$ the annual production of milk in hundredweight.

When the digestible nutrients in the feed consumed by these cows, exclusive of pasture, was compared with the nutrient requirement as computed by the Haecker Standard, it was found that for the majority of the cows the observed consumption was approximately 65 percent of the theoretical requirement, indicating that 35 percent of the nutrients may have been obtained from pasture.

THE FEED COST OF MILK AND FAT PRODUCTION AS RELATED TO YIELDS

By H. A. ROSS, Associate in Dairy Economy, H. F. HALL, First Assistant in Dairy Economy, and C. S. RHODE, Assistant Professor of Dairy Husbandry Extension

That high-producing cows require less feed for the production of a given quantity of milk or fat than do low-producing cows is generally recognized. Upon this fact rests much of the value of the work of cow-testing associations. These associations afford a practical means of determining the unprofitable cows which may well be eliminated from the herd. However, only a small percentage of the dairymen in the country are members of such associations, and most dairymen, therefore, must rely upon some other means of determining the profitableness of their various cows.

Knowledge of the amounts of milk or of butter fat which are produced by the different cows in a herd is, of course, essential to the intelligent culling out of the poor cows; but even when the yield is known, the problem of determining the minimum production which will return a profit still remains. Since this point varies with the price of feed and labor and the prices of dairy products, it is inadvisable to attempt to state specifically the amount of milk or fat which must be produced annually per cow in order to obtain a profit. It is possible, however, to compare with some accuracy the cost of feed for cows of one level of production with the cost of feed for cows of various other levels of production. This study aims to present a method whereby such comparisons can be made upon other than a "dollar and cents" basis, so that it may be used however much the prices of feeds may fluctuate.

As a basis for comparing the amounts of feed consumed, the total digestible nutrients in the feeds are used. Necessarily the accuracy of this method of determining relative costs depends on the relative uniformity for all groups of cows of the cost of feed per pound of digestible nutrients. The extent to which this cost varied and its effect upon the accuracy of the method of comparison is discussed later (page 560).

COMPARABLENESS OF RECORDS

The data on which this study is based were obtained from the records of fifteen cow-testing associations in Illinois. They were collected by the associations during the four-year period 1917-1920. The

record for each cow, which covered a period of one year, included the following data for each month: the amount of milk produced, the percentage of fat in the milk, the kind and quantity of feed consumed, and the number of days the cow was pastured. The breed, age, and date of freshening were also given. The estimated weight of the cows was reported in approximately one-half of the records.

Thousands of records of individual cows were available for study, but in order that only those which were strictly comparable might be used, careful selection was made as follows:

1. Records were considered from only those associations which were located in regions where milk was produced for fluid consumption or for condensing. By thus eliminating the herds producing for a butter-fat market, a fair degree of uniformity in seasonal production was obtained and differences in the rate of feeding resulting from price stimulation were lessened.

2. From these associations, fifteen were selected because of the known exceptional ability of the testers in charge of the work. Eleven of these fifteen men had attended agricultural colleges and all of them were noted for their conscientious attention to detail in testing milk and in weighing and recording the feed consumed. Other associations may have had equally able testers, but by taking only those of known ability it was thought that the accuracy of the records would be assured.

3. All records were discarded which were in any way incomplete. Among these were records of cows which had been removed from test before the completion of the year, records which reported the value of the roughages consumed but which failed to state the amounts in all cases, and those records which failed to give the breed or the age of the cows.

4. Records of Holstein cows only were included in the study in order to limit the range in the size of the animals and in the percentage of fat in the milk. Approximately 19 percent of these cows were pure-breds.

5. Since a significant proportion of the feed consumed by young cows is utilized for growth, records of cows under three years of age were excluded from this study.

This method of selection left 1,605 records which were deemed comparable. Slight differences in certain factors, such as the seasonal production and the percentage of fat in the milk, could not be eliminated, but such factors have been included in the tables so that their effect upon the feed consumption may be estimated.

QUANTITY OF FEED CONSUMED AS RELATED TO FAT PRODUCTION

In order to ascertain the relation between the amount of fat produced per cow per annum and the quantity of feed consumed, the 1,605 records of individual cows were divided into groups on the basis of the amount of the fat production. The average fat production per cow for the various groups, as shown by Table 1, ranged from 93 to 559 pounds, with a mean of 263 pounds for the 1,605 cows. Altho a wide production range is shown, about 90 percent of all the cows fall in the groups producing between 150 and 375 pounds of butter fat annually per cow, the number of animals in the groups producing amounts above or below these figures being very small.

The average fat content of the milk of these cows was slightly higher in those groups of greater productivity, the percentage ranging from 3.4 percent to 3.7 percent for the groups having sufficiently large numbers of cows to give comparable averages. Such a slight difference, however, probably meant very little difference in the amount of feed consumed and may therefore be ignored in comparing the nutrient consumption of the different groups of cows.

The variation among the different groups in regard to the proportionate amounts of fat produced during the pasture period (May to October) are shown in Table 1 in the form of percentages of the total annual production. If the lowest- and highest-producing groups having very few records are omitted, it will be seen that the proportion produced during the pasture period decreases as the annual fat production per cow increases. This means, of course, that the lower-producing groups consumed less feed, other than pasture, than would have been the case had they produced as large a proportion of fat in the winter months as did the cows of higher productivity. The extent to which this seasonable variation in production may have affected the feed consumption is indeterminable.

FEED EXCLUSIVE OF PASTURE THE BASIS OF COMPARISON

The only information available on the amount of feed obtained from pasture by these cows is the number of days the cows were pastured during the year. These figures have been included in Table 1, altho they are but a doubtful indication of the amount of nutrients consumed because of the extreme variability in the kind and quantity of feed afforded the different animals by the pastures. It should be noted that the number of days the cows were on pasture is greatest for the lowest-producing groups, and that the number decreases with the groups of higher production up to the group producing from 200 to 225 pounds of fat annually. For the cows producing

TABLE 1.—BUTTER FAT PRODUCTION RECORDS OF 1,605 HOLSTEIN COWS THREE YEARS OLD OR OVER

Group No.	Annual production of fat per cow	Number of cows	Average production of fat per cow	Average fat content of milk	Proportion of fat produced during the pasture period, May to October	Average length of time cows were on pasture
	lbs.		*lbs.*	*percent*	*percent*	*days*
1	75—100.....	8	93	3.3	53	207
2	100—125.....	17	114	3.3	53	218
3	125—150.....	56	138	3.4	59	196
4	150—175.....	94	161	3.4	53	190
5	175—200.....	145	188	3.5	48	181
6	200—225.....	171	213	3.5	45	176
7	225—250.....	228	237	3.5	46	174
8	250—275.....	217	261	3.5	45	175
9	275—300.....	177	287	3.5	42	173
10	300—325.....	172	312	3.6	43	173
11	325—350.....	133	337	3.7	41	173
12	350—375.....	90	361	3.6	39	169
13	375—400.....	39	386	3.6	40	168
14	400—425.....	26	412	3.7	41	176
15	425—450.....	15	435	3.7	39	176
16	450—475.....	9	465	3.7	42	156
17	475—500.....	3	480	4.0	39	162
18	500—525.....	2	517	4.0	35	153
19	525—550.....	1	526	3.3	38	61
20	550—575.....	2	559	3.5	30	153

more than this amount, the time on pasture is fairly uniform. There are two possible explanations of this relationship. On the one hand, if the somewhat questionable assumption is made that the number of days on pasture is an index of the total nutrients consumed during that time, it would seem that the poorer cows were forced to obtain their feed from pastures after the better cows had been stabled for the winter. On the other hand, the longer period of pasturing may have been the cause of the lower production by failing to furnish sufficient feed after the close of the regular pasture season.

Since in this study there is no way of definitely determining the amount of nutrients obtained from pastures, only the feed consumed other than pasture is considered in comparing the economy of the production of the different cows.

AMOUNTS OF FEED CONSUMED

The feed, exclusive of pasture, consumed by the 1,605 cows has been summarized under three heads: (1) concentrates, (2) succulent roughage, and (3) dry roughage. Table 2 shows the average amounts

TABLE 2.—AVERAGE AMOUNTS OF FEED CONSUMED IN ONE YEAR BY 1,605 HOLSTEIN COWS THREE YEARS OLD OR OVER: EXCLUSIVE OF PASTURE

As related to *fat* production

Group No.	Number of cows	Average production of fat per cow	Feed consumed per cow			Feed consumed per pound of fat produced		
			Concentrates	Succulent roughage	Dry roughage	Concentrates	Succulent roughage	Dry roughage
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
1	8	93	688	4 985	1 534	7.4	53.6	16.5
2	17	114	1 231	5 198	1 482	10.8	45.6	13.0
3	56	138	883	6 058	1 628	6.4	43.9	11.8
4	94	161	1 336	6 408	1 546	8.3	39.8	9.6
5	145	188	1 391	5 640	1 918	7.4	30.0	10.2
6	171	213	1 576	6 326	2 109	7.4	29.7	9.9
7	228	237	1 754	6 541	2 086	7.4	27.6	8.8
8	217	261	1 827	6 629	2 192	7.0	25.4	8.4
9	177	287	2 038	6 630	2 353	7.1	23.1	8.2
10	172	312	2 309	6 302	2 122	7.4	20.2	6.8
11	133	337	2 292	7 043	2 258	6.8	20.9	6.7
12	90	361	2 744	6 823	2 347	7.6	18.9	6.5
13	39	386	2 856	7 411	2 277	7.4	19.2	5.9
14	26	412	2 760	7 004	2 060	6.7	17.0	5.0
15	15	435	2 784	5 873	2 219	6.4	13.5	5.1
16	9	465	3 534	5 673	2 464	7.6	12.2	5.3
17	3	480	2 304	8 880	4 080	4.8	18.5	8.5
18	2	517	3 877	6 980	1 810	7.5	13.5	3.5
19	1	526	4 997	11 835	3 945	9.5	22.5	7.5
20	2	559	4 472	7 547	1 677	8.0	13.5	3.0

of these classes of feeds consumed annually per cow and per pound of fat for the various production groups.

The consumption of concentrates bears a consistent relation to the amount of fat produced by the cows in the different groups. In other words, there evidently was a tendency to feed the cows in each herd a uniform amount of grain for each pound of fat produced, regardless of the individual production of the cows. The average amount of concentrates consumed per pound of fat for all the cows whose records were studied is 7.3 pounds, and the average of each group varies but little from the average of all, except in those groups having only a few cows.

Succulent roughage consisted almost entirely of corn silage, altho small amounts of green corn, beets, and wet malt were included. If the groups having very few records are omitted, it will be seen that the succulent roughage was consumed in amounts ranging from approximately 6,000 pounds per cow in the lowest-producing groups, to 7,400 pounds per cow in the highest-producing groups. However, the amount of succulent roughage consumed per pound of fat produced decreases rapidly with the increase in production, ranging from 44

pounds for the low-producing cows to 19 pounds for the high-producing cows. Many of the dairymen managing the herds from which records were obtained fed each cow in the herd the same amount of silage, while others varied the quantity of silage somewhat but not in proportion to the production of milk or butter fat.

The relation between dry roughage consumed and pounds of fat produced is similar to the relation between silage consumed and fat produced. The amount of dry roughage ranges from 1,600 pounds to 2,300 pounds per cow, or from approximately 12 to 6 pounds per pound of fat.

DIGESTIBLE NUTRIENTS IN FEED CONSUMED

Three facts concerning the feed consumption of these cows are apparent from the data in Table 2. These are: (1) Approximately the same amount of concentrates, per pound of fat produced, was consumed by the high-producing cows as was consumed by the low-producing cows. (2) The amount of succulent roughage consumed, per pound of fat produced, decreased as the production per cow increased. (3) In like manner, the consumption of dry roughage, per pound of fat produced, decreased with the increase in production. These facts indicate that, in so far as feed consumption is concerned, high-producing cows are more economical producers of fat than are low-producing cows. However, if a quantitative comparison of the groups is to be made, it is necessary to reduce the three classes of feed to a common unit. In this study, total digestible nutrients have been selected as the basis of comparison.

Using the analyses given by Henry and Morrison,[1] the amounts of total digestible nutrients in the feeds consumed by each cow individually were computed. In the case of the various grains, roughages, and common by-products, these values were applied directly, but for certain commercial mixed feeds the computation of the amount of digestible nutrients involved some estimates. The list of grains and by-products used in compounding these feeds was available, but the proportions in which they were combined were not known. A formula for each feed, based upon the list of ingredients and upon the protein, carbohydrate, fat, and fiber content as guaranteed by the manufacturer was therefore assumed, and the amount of digestible nutrients in the mixed feed was then computed upon the basis of the assumed formula. Such a method was considered sufficiently accurate for a study of this kind, and it is probable that no more error is involved than is involved in the assumption of uniform quality of the grains and roughages (which is made when average values are used in computing the digestible nutrient content). The amounts of these mixed feeds were comparatively small, and they were scattered

[1]Feeds and Feeding. 15th ed. (1915), pp. 653-666.

thruout the various groups, so that any errors involved would have practically no bearing upon the relative economy of the fat production of the various groups.

In Table 3 are shown the amounts of digestible nutrients in the concentrates, in the succulent roughage, in the dry roughage, and in the total feed consumed, for each pound of fat produced. There is a significant negative correlation ($-0.4570 \pm .0133$) between the annual production of butter fat per cow and the nutrient consumption per pound of fat produced. The total digestible nutrients consumed per pound of fat produced range from approximately 22 pounds in the two lowest-producing groups to 10 pounds in the groups with the highest production. The decrease in the consumption of nutrients per pound of fat produced, with the increase in production per cow, is expressed by the formula, $Y = \frac{2584.22}{X + 48.06} + 5.18$; in which $Y =$ the pounds of digestible nutrients consumed per pound of fat produced, and $X =$ the total production of fat during the

TABLE 3.—DIGESTIBLE NUTRIENTS IN FEED CONSUMED IN ONE YEAR BY 1,605 HOLSTEIN COWS THREE YEARS OLD OR OVER: EXCLUSIVE OF PASTURE

As related to *fat* production

Group No.	Number of cows	Average production of fat per cow	Digestible nutrients consumed per pound of fat produced				
			Concentrates	Succulent roughage	Dry roughage	All feed	
						Observed	Computed[1]
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
1	8	93	5.3	9.4	8.1	22.8	23.5
2	17	114	7.7	8.1	6.1	21.9	21.1
3	56	138	4.6	7.9	5.8	18.3	19.1
4	94	161	6.0	7.0	4.6	17.6	17.5
5	145	188	5.5	5.3	4.6	15.4	16.1
6	171	213	5.5	5.2	4.7	15.4	15.1
7	228	237	5.5	4.8	4.0	14.3	14.3
8	217	261	5.3	4.5	3.9	13.7	13.5
9	177	287	5.3	4.1	3.8	13.2	12.9
10	172	312	5.6	3.6	3.1	12.3	12.4
11	133	337	5.1	3.6	3.2	11.9	11.9
12	90	361	5.7	3.4	3.1	12.2	11.5
13	39	386	5.6	3.3	2.8	11.7	11.1
14	26	412	5.1	2.9	2.4	10.4	10.8
15	15	435	4.8	2.4	2.6	9.8	10.5
16	9	465	5.5	2.1	2.5	10.1	10.2
17	3	480	3.8	3.3	3.5	10.6	10.1
18	2	517	5.5	2.3	1.7	9.5	9.8
19	1	526	7.2	4.1	3.0	14.3	9.7
20	2	559	6.2	2.5	1.5	10.2	9.4

[1]From fitted curve.

year in pounds.[1] As shown by Fig. 1, the theoretical curve fits closely the actual data for all groups except Group 19, which includes but one animal. Hence it may be concluded that within the limits of the production range shown here, the amount of nutrients consumed per pound of fat produced decreases at an ever-decreasing rate as the production per cow increases. Stated in other words, the curve indicates that as a dairyman increases the potential production ability of his herd he decreases the feed cost of producing a pound of fat; and furthermore, this decrease is more rapid in going from a very low production to the average, than it is in going from the average to a high production.

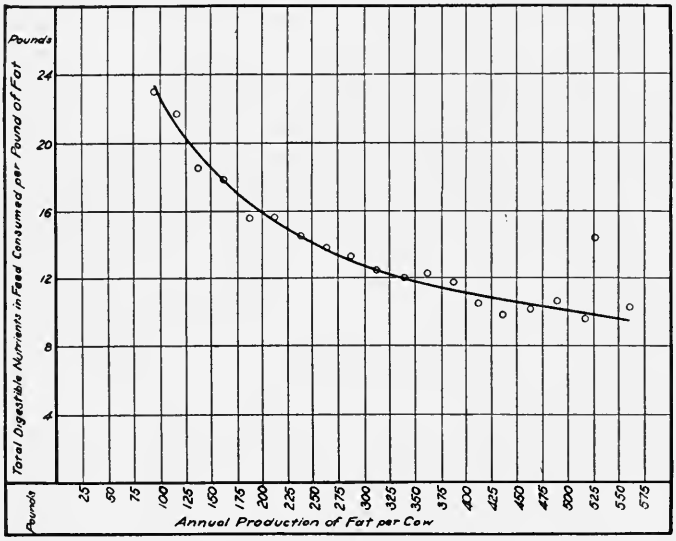

FIG. 1.—THE CONSUMPTION OF DIGESTIBLE NUTRIENTS AS RELATED TO FAT PRODUCTION (See Table 3)

DIGESTIBLE NUTRIENTS AS A BASIS FOR COMPARING THE FEED COST OF FAT PRODUCTION

The high-producing cows in this study consumed a greater proportion of concentrates than did the low-producing cows; and since the cost of concentrates per pound of nutrients is normally higher than the cost of roughages, it might appear that to use the nutrient consumption as a basis of comparing feed costs would involve a serious error. This would be particularly true if the records of cows pro-

[1] The formulas used in this study were derived by the use of the straight line method. Running, Theodore R. Empirical Formulas, pp. 53-56, 1917.

ducing for a butter-fat market had been included in this study, because the majority of such cows produce the greater part of their milk on pasture and are fed largely on cheap roughages during the winter. However, as was stated previously (page 554), the records of those cows only which were producing for a whole-milk, or year-round, market were included in the study. Altho these cows were not, of course, all managed in the same way, the variation in the cost of feed per pound of nutrients was less than would have been the case had cows in butter-fat regions been included.

In order to determine the variation in the cost of the rations of these cows, the amounts of the various kinds of feed consumed were tabulated and the cost of feed per pound of digestible nutrients was computed for each group for each year of the fifteen-year period 1908-1922. The computations were based upon the current values of the feeds consumed. Corn, oats, barley, and hay were figured at the average of Illinois farm values for each month; silage was valued at its hay and corn equivalent.[1] Bran, cottonseed meal, linseed oil meal, middlings, hominy feed, gluten feed, and commercial mixed feed prices were figured at the average daily Chicago wholesale prices, plus sums representing the cost of freight, the dealer's profit, and the cost of hauling the feed to the farm.[2]

Table 4 shows the slight variation in the cost of nutrients for each of the nine largest groups (Nos. 4 to 12). The other groups are omitted because the number of cows included is insufficient to give comparable averages. It may be seen from this table that even during the years 1917 to 1921, when the cost of concentrates was relatively much higher than the cost of roughages, the greatest difference in the cost of feed for any two groups amounted to only about one-tenth of a cent per pound of digestible nutrients. The maximum variation between any two groups in the average cost per pound of nutrients for the entire fifteen years was only six hundredths of a cent. In other words, the average cost of feed consumed by Group 12, per pound of fat produced, is found to be 21.0 cents (11.5×1.83). If the cost of this same group were computed on the basis of the cheapest ration (Group 6), the cost per pound of fat would be 20.4 cents (11.5×1.77), a difference of less than one cent.

It should be pointed out that the cost of the feeds for each year was computed from the proportionate amounts of the various kinds consumed during the period of the study, 1917 to 1920; and that these proportions might have been somewhat different in the earlier

[1] Pearson, F. A., and Gaines, W. L. The Evaluation of Corn Silage. (unpublished data).

[2] The total amounts per ton added to the wholesale price are as follows: 1908 to 1915, $4.50; 1916, $5.50; 1917 and 1918, $7.00; 1919, $8.00; 1920, $8.50; 1921, $7.00; and 1922, $6.00.

TABLE 4.—COST PER POUND OF DIGESTIBLE NUTRIENTS CONSUMED BY COWS IN GROUPS 4 TO 12 INCLUSIVE[1]
AVERAGE OF ALL FEEDS EXCEPT PASTURE
As related to *fat* production

Group No.	4	5	6	7	8	9	10	11	12	Greatest difference between any two groups
Average annual fat production per cow, *lbs.*	(161)	(188)	(213)	(237)	(261)	(287)	(312)	(337)	(361)	
Year	*cents*	*cents*	*cents*	*cents*	*cents*	*cents*	*cents*	*cents*	*cents*	*cents*
1922[2]	1.45	1.41	1.40	1.41	1.38	1.41	1.41	1.45	1.45	.07
1921	1.56	1.53	1.52	1.52	1.51	1.51	1.50	1.54	1.54	.06
1920	3.04	3.00	2.97	2.99	2.99	2.98	3.01	3.04	3.07	.10
1919	2.93	2.87	2.85	2.88	2.87	2.86	2.90	2.93	2.96	.11
1918	2.68	2.64	2.63	2.66	2.65	2.66	2.71	2.71	2.72	.09
1917	2.42	2.36	2.35	2.38	2.37	2.38	2.43	2.43	2.46	.11
1916	1.53	1.51	1.51	1.52	1.52	1.52	1.54	1.55	1.57	.06
1915	1.52	1.51	1.51	1.52	1.53	1.52	1.54	1.55	1.56	.05
1914	1.55	1.53	1.53	1.54	1.53	1.54	1.54	1.55	1.56	.03
1913	1.38	1.37	1.36	1.36	1.36	1.36	1.37	1.39	1.38	.03
1912	1.65	1.64	1.64	1.65	1.64	1.64	1.65	1.66	1.66	.02
1911	1.44	1.42	1.42	1.42	1.42	1.41	1.41	1.44	1.42	.03
1910	1.34	1.32	1.32	1.34	1.33	1.33	1.33	1.35	1.35	.03
1909	1.31	1.29	1.29	1.32	1.32	1.33	1.36	1.35	1.36	.07
1908	1.32	1.30	1.30	1.33	1.33	1.33	1.37	1.36	1.36	.07
Average	1.81	1.78	1.77	1.79	1.78	1.79	1.80	1.82	1.83	.06

[1]The cost of corn, oats, barley, and hay is based upon data obtained from the Division of Crop and Livestock Estimates, U. S. Department of Agriculture; the cost of mill feeds, upon the quotations of the Western Feed Market Bureau, Milwaukee, Wis.; and the cost of commercial feeds, upon prices of Sucrene Dairy Feed obtained from the American Milling Company, Peoria, Ill.

[2]First 9 months.

years because of the varying prices of concentrates and roughages. It would appear, however, that the nutrient basis of comparison is sufficiently accurate for the practical purposes of this study.

RELATIVE FEED COST OF BUTTER FAT PRODUCTION

Since, therefore, the cost of nutrients in the rations of dairy cows of varying fat production, appears to be fairly uniform, the feed cost of the fat produced may be compared by the use of the preceding formula. In Table 5 are presented several such comparisons. The relative nutrient consumption indicates, in a general way, the relative feed cost, which is expressed here in terms of percentages, the nutrients consumed by a group of cows with an average production of 350 pounds of fat being used as a base. It may be noted that the feed cost of producing a pound of fat is twice as great with cows of but 100 pounds annual production as it is with cows of 350 pounds annual production. Altho it is evident that the cost of feed for any one cow or for any one herd of cows may vary widely from the average, it would seem that these data show, with considerable accuracy, the relative feed cost of producing fat with cows of various production levels.

TABLE 5.—RELATIVE FEED COST OF PRODUCING ONE POUND OF FAT WITH COWS OF DIFFERENT ANNUAL PRODUCTIONS

Based upon digestible nutrient consumption exclusive of pasture

Annual production of fat per cow	[1]Digestible nutrients consumed per pound of fat produced	Relative feed cost per pound of fat produced
lbs.	*lbs.*	*percent*
350	11.67	100
325	12.11	104
300	12.60	108
275	13.18	113
250	13.85	119
225	14.64	125
200	15.60	134
175	16.77	144
150	18.23	156
125	20.11	172
100	22.63	194

[1]Computed from the fitted curve.

QUANTITY OF FEED CONSUMED AS RELATED TO MILK PRODUCTION

In order to determine the relative feed cost of the milk produced by these cows, the 1,605 records were divided into groups on the basis of the yearly milk production per cow. The average production of the various groups, as shown by Table 6, ranged from 3,081 pounds

to 16,711 pounds, with an average of 7,506. When the cows were grouped on this basis, the average percentage of fat in the milk produced by the various groups was found to decrease slightly with the increase in production, ranging from 3.6 percent to 3.3 percent for the groups of sufficient size to be considered. Probably, slightly less feed was required for the production of 100 pounds of milk with the lower fat content than was required for the production of the higher testing milk. However, the difference in the amount of feed consumed that may be attributed to the variation in the fat content of the milk was undoubtedly less than the difference in feed consumption due to the seasonal variation in production. The higher-producing cows produced a greater proportion of milk during the winter months than did the lower-producing cows. This means, of course, that they consumed more feed, other than pasture, than they would have consumed had they produced the same proportion of milk during the winter months as did the lower-producing cows. These two factors affecting feed consumption (variation in fat content of milk and differences in seasonal production) cannot be eliminated, but as the two tend to counterbalance, the error introduced in the study is thereby lessened.

TABLE 6.—MILK PRODUCTION RECORDS OF 1,605 HOLSTEIN COWS THREE YEARS OLD OR OVER

Group No.	Annual production of milk per cow	Number of cows	Average production of milk per cow	Average fat content of milk	Proportion of milk produced during the pasture period, May to October	Average length of time cows were on pasture
	lbs.		*lbs.*	*percent*	*percent*	*days*
1	2 500— 3 500	21	3 081	3.6	49	205
2	3 500— 4 500	79	4 094	3.6	57	200
3	4 500— 5 500	183	5 065	3.6	50	186
4	5 500— 6 500	254	6 032	3.6	46	176
5	6 500— 7 500	309	7 013	3.6	45	175
6	7 500— 8 500	266	7 972	3.5	43	171
7	8 500— 9 500	221	8 956	3.5	42	170
8	9 500—10 500	137	9 938	3.4	41	175
9	10 500—11 500	76	10 921	3.4	41	163
10	11 500—12 500	33	11 943	3.3	39	172
11	12 500—13 500	19	12 865	3.3	41	155
12	13 500—14 500	4	13 710	3.3	38	175
13	14 500—15 500	1	15 389	3.4	33	152
14	15 500—16 500	1	15 825	3.3	38	63
15	16 500—17 500	1	16 711	3.4	28	152

FEED CONSUMED AND TOTAL DIGESTIBLE NUTRIENTS IN FEED

Table 7 shows the amount of feed consumed both per cow and per 100 pounds of milk produced. Practically the same relation obtains here as was found when the comparison was made on a butter-fat

TABLE 7.—AVERAGE AMOUNTS OF FEED CONSUMED IN ONE YEAR BY 1,605 HOLSTEIN COWS THREE YEARS OLD OR OVER: EXCLUSIVE OF PASTURE

As related to *milk* production

Group No.	Number of cows	Average production of milk per cow	Feed consumed per cow			Feed consumed per 100 pounds of milk produced		
			Concentrates	Succulent roughage	Dry roughage	Concentrates	Succulent roughage	Dry roughage
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
1	21	3 081	746	5 318	1 500	24.2	172.6	48.7
2	79	4 094	1 060	5 764	1 498	25.9	140.8	36.6
3	183	5 065	1 352	5 926	1 783	26.7	117.0	35.2
4	254	6 032	1 562	6 279	1 997	25.9	104.1	33.1
5	309	7 013	1 767	6 494	2 167	25.2	92.6	30.9
6	266	7 972	1 993	6 744	2 280	25.0	84.6	28.6
7	221	8 956	2 230	6 762	2 311	24.9	75.5	25.8
8	137	9 938	2 564	6 748	2 365	25.8	67.9	23.8
9	76	10 921	2 829	6 684	2 184	25.9	61.2	20.0
10	33	11 943	3 117	6 139	2 054	26.1	51.4	17 2
11	19	12 865	3 769	6 600	2 522	29.3	51.3	19.6
12	4	13 710	2 989	4 456	2 399	21.8	32.5	17.5
13	1	15 389	4 386	8 464	1 924	28.5	55.0	12.5
14	1	15 825	4 985	11 869	3 561	31.5	75.0	22.5
15	1	16 711	4 261	5 849	2 089	25.5	35.0	12.5

TABLE 8.—DIGESTIBLE NUTRIENTS IN FEED CONSUMED IN ONE YEAR BY 1,605 HOLSTEIN COWS THREE YEARS OLD OR OVER: EXCLUSIVE OF PASTURE

As related to *milk* production

Group No.	Number of cows	Average production of milk per cow	Digestible nutrients consumed per 100 pounds of milk produced				
			Concentrates	Succulent roughage	Dry roughage	All feed	
						Observed	Computed[1]
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
1	21	3 081	17.1	30.1	23.7	70.9	69.0
2	79	4 094	18.3	25.5	17.6	61.4	62.0
3	183	5 065	19.2	20.6	16.5	56.3	56.7
4	254	6 032	19.1	18.5	15.5	53.1	52.6
5	309	7 013	18.6	16.6	14.5	49.7	49.1
6	266	7 972	18.8	15.0	13.2	47.0	46.3
7	221	8 956	19.0	13.4	11.9	44.3	43.9
8	137	9 938	19.3	12.0	10.8	42.1	41.8
9	76	10 921	19.6	10.8	9.7	40.1	40.0
10	33	11 943	19.7	9.0	8.3	37.0	38.3
11	19	12 865	22.5	8.8	9.2	40.5	37.0
12	4	13 710	15.8	6.0	7.5	29.3	36.0
13	1	15 389	23.9	10.0	5.3	39.2	34.1
14	1	15 825	22.5	13.5	10.5	46.5	33.7
15	1	16 711	19.5	7.5	4.5	31.5	32.9

[1]From fitted curve.

basis. The amount of concentrates consumed per 100 pounds of milk produced is approximately constant for all groups, while the amounts of succulent and dry roughages per unit of product decrease as the production increases.

The total digestible nutrients in the feed consumed per 100 pounds of milk produced (Table 8) decrease at an ever-decreasing rate with the increase in production, in a manner similar to the decrease in nutrients with the increase in fat production (Table 3 and Fig. 1). The correlation between milk production and nutrient consumption per hundredweight of milk is —0.4180 ± .0139, as compared with the fat production and nutrient consumption correlation of —0.4570 ± .0133. The fitted curve shown in Fig. 2 is expressed by the formula $Y = \frac{3651.60}{X + 36.75} + 14.95$; in which Y = the pounds of digestible nutrients consumed per 100 pounds of milk produced, and X = the annual production of milk in hundredweight.

The relative feed cost of producing milk with cows of different annual productions may be computed by the use of this formula in the same way that the relative feed cost of fat production was computed. Table 9 shows such a comparison, the nutrients consumed by cows producing 10,000 pounds annually being used as a base. Any other production would serve equally well as a basis of comparison; the one used is selected merely for illustration. In this case the cost of feed per 100 pounds of milk was 67 percent greater for the 3000-pound cows than for the 10,000 pound cows.

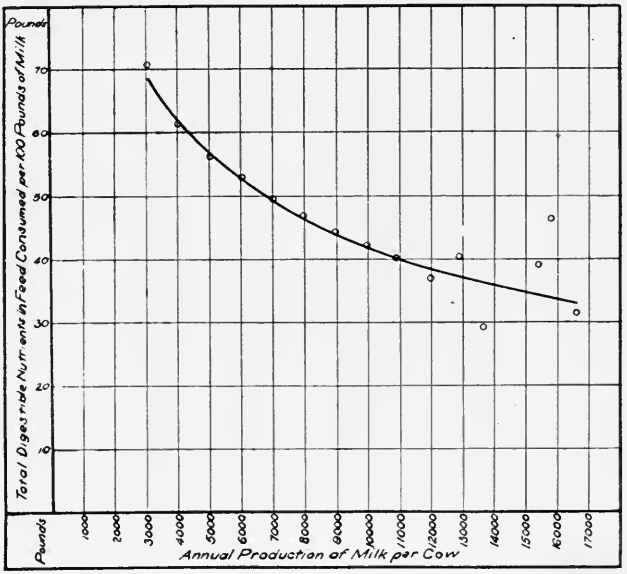

FIG. 2.—THE CONSUMPTION OF DIGESTIBLE NUTRIENTS AS RELATED TO MILK PRODUCTION (See Table 8)

TABLE 9.—RELATIVE FEED COST OF PRODUCING 100 POUNDS OF MILK WITH COWS OF DIFFERENT ANNUAL PRODUCTIONS

Based upon digestible nutrient consumption exclusive of pasture

Annual production of milk per cow	[1]Digestible nutrients consumed per 100 pounds of milk produced	Relative feed cost per 100 pounds of milk produced
lbs.	*lbs.*	*percent*
10 000.....	41.7	100
9 000.....	43.8	105
8 000.....	46.2	111
7 000.....	49.2	118
6 000.....	52.7	126
5 000.....	57.0	137
4 000.....	62.5	150
3 000.....	69.7	167

[1]Computed from the fitted curve.

NUTRIENTS OBTAINED FROM PASTURE

Altho the data in this study do not include figures on the amount of nutrients obtained from pasture, these figures may be computed by an indirect method. Such a method involves the assumption that the difference between the observed nutrient consumption of these cows and the nutrient requirement as computed by a feeding standard represents the nutrients obtained from pasture. This is, of course, rather a broad assumption; but in view of the lack of information concerning the proportion of feed that is obtained from pasture under practical farm conditions, it seems worth while to present these data for whatever they are worth.

The digestible nutrient requirement per 100 pounds of milk was computed according to the Haecker Feeding Standard,[3] account being taken of the weights of these cows and of the fat content of the milk. From this computed requirement were deducted the nutrients in the feed consumed exclusive of pasture, which are given in Table 8. The result is the computed amount of nutrients obtained from pasture. Table 10 and Fig. 3 show that the low-producing cows obtained a much greater proportion of their feed from pasture than did the high-producing cows. This conclusion is supported by the fact that the low-producing cows were on pasture a longer time and produced a relatively greater proportion of the milk during the pasture period (Table 11).

These data indicate that a surprisingly high percentage of the total nutrients consumed were obtained from pasture. If such a comparison of the feeding standard requirement and the observed nutrient consumption is valid, each of the groups of cows obtained over one-third of the feed from this source, altho, for most of the groups, less than

[3] See reference bearing this number, page 573.

45 percent of the total year's production came in the pasture period from May to October.

TABLE 10.—COMPARISON OF THE AMOUNT OF NUTRIENTS REQUIRED TO PRODUCE 100 POUNDS OF MILK AS COMPUTED BY THE HAECKER FEEDING STANDARD, AND THE OBSERVED NUTRIENT CONSUMPTION EXCLUSIVE OF PASTURE

Group No.	Average production of milk per cow	[1]Weight of cows	Age of cows	Average fat content of milk	Total digestible nutrients in feed consumed per 100 pounds of milk produced		
					Required by the Haecker Feeding Standard	[3]Consumed by the 1,605 cows in this study (pasture excluded)	Difference between feeding standard requirement and observed consumption
	lbs.	*lbs.*	*yrs.*	*percent*	*lbs.*	*lbs.*	*lbs.*
1	3 081	968	6.0	3.6	122.2	69.0	53.2
2	4 094	993	5.0	3.6	101.5	62.0	39.5
3	5 065	1 018	5.1	3.6	89.4	56.7	32.7
4	6 032	1 042	5.7	3.6	81.3	52.6	28.7
5	7 013	1 066	5.9	3.6	75.3	49.1	26.2
6	7 972	1 090	6.1	3.5	70.6	46.3	24.3
7	8 956	1 115	6.2	3.5	67.0	43.9	23.1
8	9 938	1 139	6.5	3.4	63.1	41.8	21.3
9	10 921	1 164	6.6	3.4	60.7	40.0	20.7
10	11 943	1 190	7.0	3.3	58.7	38.3	20.4
11	12 865	1 216	6 4	3.3	57.2	37.0	20.2
12	13 710	1 232	7.0	3.3	55.9	36.0	19.9
13	15 389	1 276	7.5	3.4[2]	53.9	34.1	19.8
14	15 825	1 287	4.5	3.3	53.4	33.7	19.7
15	16 711	1 309	7.5	3.4[2]	52.6	32.9	19.7

[1]Approximately half the records give the weights of the cows, and the estimated weights presented in this table are based upon the averages of these records.

[2]Groups 13 and 15 include but one cow each, and in computing the nutrient requirement by the use of the Haecker Standard, a uniform test of 3.3 percent has been used for these two groups.

[3]Computed from the fitted curve.

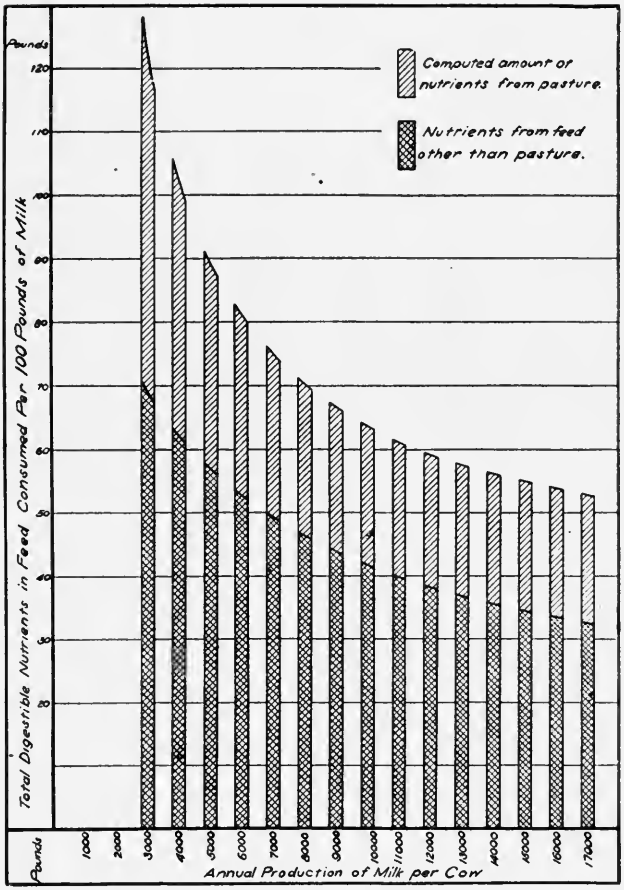

FIG. 3.—AMOUNT OF NUTRIENTS REQUIRED TO PRODUCE 100 POUNDS OF MILK, AS COMPUTED BY THE HAECKER FEEDING STANDARD AND THE OBSERVED NUTRIENT CONSUMPTION EXCLUSIVE OF PASTURE

Tho the difference between the observed nutrient consumption and the theoretical requirement based on Haecker's Standard may not be an exact measurement of the amount of nutrients obtained from pasture, it may be taken as a rough approximation.

TABLE 11.—COMPARISON OF THE PROPORTION OF MILK PRODUCED DURING THE PASTURE PERIOD, THE LENGTH OF TIME THE COWS WERE ON PASTURE, AND THE COMPUTED PROPORTION OF NUTRIENTS OBTAINED FROM PASTURE

Group No.	Production of milk per cow	Proportion of milk produced during the pasture period, May to October	Average length of time cows were on pasture	[1]Computed proportion of total nutrients consumed during the year, obtained from pasture
	lbs.	*percent*	*days*	*percent*
1	3 081	49	205	43.5
2	4 094	57	200	38.9
3	5 065	50	186	36.6
4	6 032	46	176	35.3
5	7 013	45	175	34.8
6	7 972	43	171	34.4
7	8 956	42	170	34.5
8	9 938	41	175	33.8
9	10 921	41	163	34.1
10	11 943	39	172	34.8
11	12 865	41	155	35.3
12	13 710	38	175	35.6
13	15 389	33	152	36.7
14	15 825	38	63	36.9
15	16 711	28	152	37.5

[1]The difference between the nutrient requirement per 100 pounds of milk, as computed by the Haecker Standard, and the observed consumption is assumed to represent the nutrients obtained from pasture.

FORCED FEEDING FOR MAXIMUM YIELDS AND FEED COST OF PRODUCTION

In order to avoid possible misinterpretation in the application of these data on the relative feed cost of milk and fat production, it should perhaps be stated that the study does not show that the most economical production is obtained by feeding for maximum production. It does show that cows of inherently high production ability are more economical producers than cows of low production ability. A clear distinction should be made between these two factors (rate of feeding and inherent production ability) which tend to determine yield, because the economy of production is quite different in the two cases.

If a cow is given increasing amounts of feed, a point is eventually reached where the increased milk flow is not proportional to the increase in feed. In feeding for maximum production, this point of greatest efficiency is passed, and the feed consumed per unit of product is usually greater than it would have been had the cow been fed a somewhat lighter ration. This is well illustrated by Holtsmark's work based on 846 dairy herds in Norway.[4] Table 12, taken from

[4] See reference bearing this number, page 573.

his study, shows that the yield of milk for each 100 feed units increases up to the third group, which received 2,500 feed units. This represents the point of greatest efficiency; the groups of cows which were fed more than this amount showed decreasing yields of milk for each 100 feed units consumed.

TABLE 12.—RELATION BETWEEN THE AMOUNT OF FEED CONSUMED AND THE MILK PRODUCED BY 846 DAIRY HERDS IN NORWAY
According to Holtsmark

Number of feed units consumed per cow	Yield of milk per cow	Yield of milk per 100 feed units
	kilograms	*kilograms*
1 500.....	923	61.5
2 000.....	1 424	71.2
2 500.....	1 813	72.5
3 000.....	2 131	71.0
3 500.....	2 399	68.5
4 000.....	2 632	65.8
4 500.....	2 837	63.1

In contrast to feeding for maximum production is the building up of a herd of cows with the idea of increasing their potential production ability. As the herd is improved and the production per cow increased, the relative amount of feed required for maintenance becomes smaller and smaller and the feed consumed per unit of product continues to decrease, altho at a very slow rate for high-producing cows. Stated in other words, in so far as the feed cost of milk and fat production is concerned, feeding for maximum production is subject to the economic law of increasing costs, while increasing the potential ability for high production is subject to the law of decreasing costs.

The cows included in this study were cared for by practical farmers producing milk for profit. It may be assumed that, with the exception of a few animals which were on official test, these cows were fed with the idea of producing a large amount of milk as economically as possible. This does not mean that each farmer fed to the point of greatest economic efficiency but, since high- and low-producing cows were found in the same herds, it is probable that the means of the larger groups represent cows fed to approximately the same point as regards efficiency in the utilization of feed. It is quite possible that the lowest-producing cows may have been underfed and the extremely high-producing groups, overfed. In general, however, the variation in the production of the cows studied appears to have been due to the inherent differences in production ability rather than to differences in feeding. The data in Tables 5 and 9 may therefore be taken as representing approximately the relative economy of fat and milk production by high- and by low-producing cows.

CONCLUSIONS

From this study of 1,605 Holstein cows, three years old or over, it may be concluded that the annual production of milk and fat per cow and the nutrient consumption per unit of product are negatively correlated. As production is increased by increasing the potential production ability of a herd, the amount of nutrients consumed per unit of product decreases at an ever-decreasing rate. This relation is expressed by hyperbolic curves. As long as the cost of nutrients in the rations of dairy cows is fairly uniform, these curves may be used to compare the relative feed cost, exclusive of pasture, of milk and fat production for cows similar to those studied if they are fed and cared for in a like manner.

If it is assumed that the difference between the amount of nutrients required, as given by the Haecker Standard, and the amount consumed by these cows in concentrates, succulent roughage, and dry roughage, represents the nutrients obtained from pasture, it would appear that the majority of these cows obtained from pasture approximately 35 percent of the total nutrients consumed.

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